Effect of Field Temperatures on Development for Egg Stage of *Pieris rapae crucivora* (Lepidoptera, Pieridae)

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Synopsis: Relation between field temperatures and development for egg stage of *Pieris rapae crucivora* clarified that developmental velocity of eggs shifts seasonally and probably locally, and that eggs develop more rapidly under constant temperature conditions than under fluctuating temperature conditions.

Effect of temperature on developmental velocity has so far been surveyed under constant temperatures in the laboratory (WADA and KOBAYASHI, 1980; OHSAKI, 1982). But it has been known that rearing conditions under constant temperatures have a different effect on insect development from fluctuating or alternating temperatures at the same temperature level (MIYASHITA, 1972).

The aim of the present paper is twofold, first to answer the question whether developmental zero of *Pieris rapae crucivora* BOISDUVAL is different among generations and/or localities, secondarily to compare developmental velocity of eggs reared under constant temperatures in the laboratory with that of eggs living under meteorological, fluctuating temperatures in the field.

Materials and Methods

Developmental duration ($=D$) for egg stage of the butterfly was surveyed in the field by individually recording the calendar date of oviposition and hatching. Totally, 176 eggs were observed in the first generation ($=G_1$, 7th May~14th June), 291 in the second generation ($=G_2$, 23rd June~7th August), 254 in the third generation ($=G_3$, 8th August~5th September), 155 in the fourth generation ($=G_4$, 10th September~14th October) at the campus of Hokkaido University, 1975.

The maximum, minimum, and mean air temperatures (°C) and sunshine duration (hr) were cited from the Sapporo Meteorological Observatory, about 2km south-west of the area surveyed. The daily mean air temperatures, (max. - min.) / 2, were averaged from the day of oviposition until the day of hatching. Linear regression equations of developmental velocity to the average of the mean air temperatures were calculated based upon the data obtained.

Results and Discussion

1. *Seasonal shift of developmental zero*

Average of developmental velocity ($=1 / D$) is plotted against mean temperatures for each generation in Fig. 1, together with 95% confidence limits on the cases of observation over 10 individuals. Deviated values caused by a lower (12 °C in G_1, 17 °C in G_2, 20 °C in G_3, 10 °C in G_4) and higher temperature condition (18 °C in G_1, 26 °C in G_2, 25 °C in G_3, 19 °C in G_4), and by scarce sampling cases were omitted to calculate the regression lines. Table 1 shows regression equations of each gen-

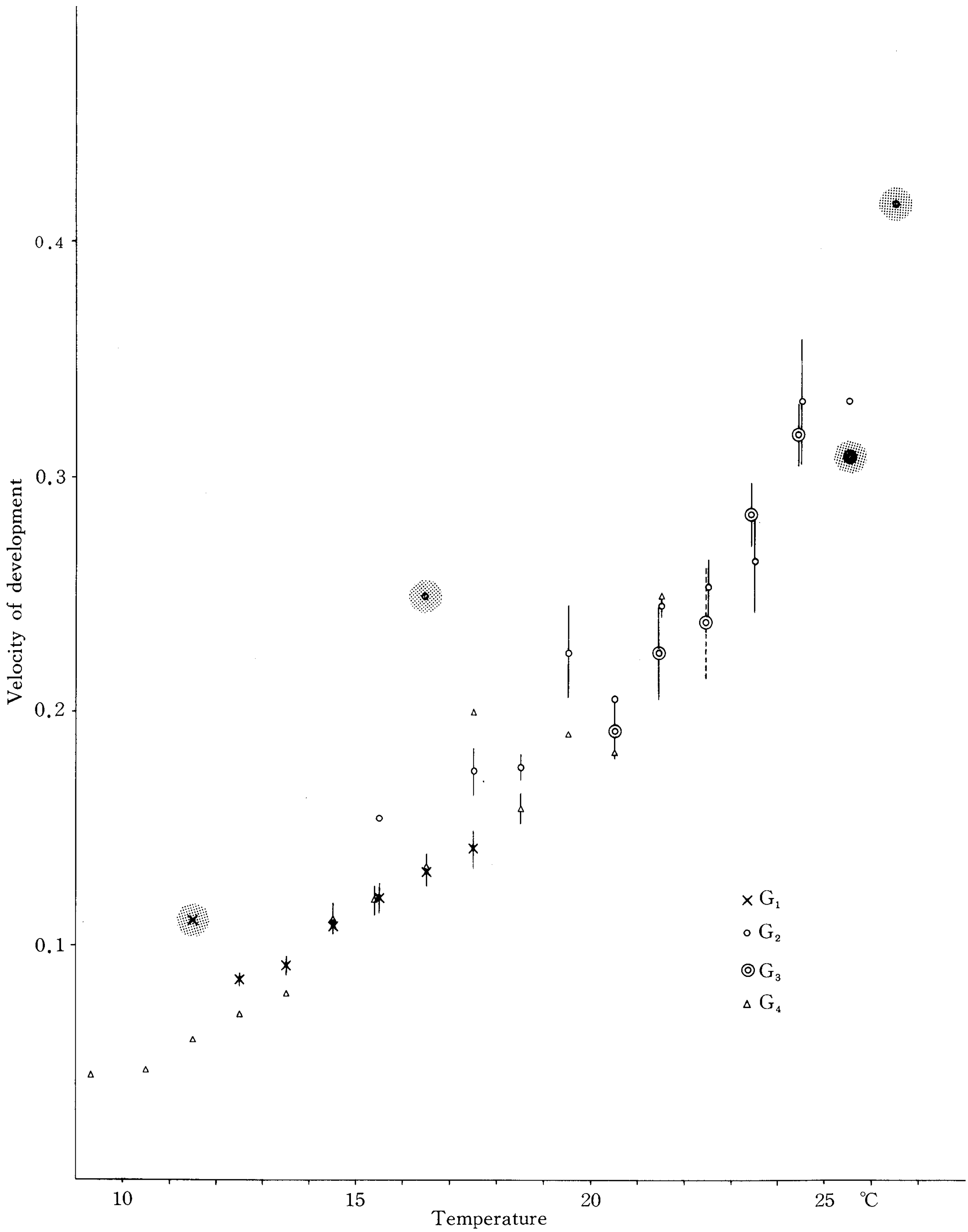

Figure 1 Relation between developmental velocity and average of mean air temperatures in four generations, G_1, G_2, G_3, and G_4. Hatched cases were omitted to calculate the regression lines.

Table 1 Regression equations between mean temperature (T) and developmental velocity (V) of eggs for each generation, compared with that obtained by OHSAKI (1982). r: Correlation coefficient, t: Developmental zero, K: Thermal constant.

Generation	Regression equation	r	Average T (Range)	Average (max.−min.) temperature ±S.D.	t(°C)	K
G_1	$V=0.0131T-0.0819$	0.816(N=173)	14.5(12.1~17.6)	8.6±4.0	6.3	76.4
G_2	$V=0.0205T-0.1945$	0.823(N=284)	20.5(17.2~25.7)	6.9±2.9	9.5	48.9
G_3	$V=0.0296T-0.4102$	0.646(N=233)	23.1(20.3~24.9)	7.8±3.1	13.9	33.8
G_4	$V=0.0141T-0.0953$	0.831(N=150)	16.2(10.7~21.0)	8.8±2.3	6.8	70.9
OHSAKI'S	$V=0.0190T-0.1389$	0.998	20.0(15.0~25.0)		7.3	52.6

Table 2 The 95% confidence limits of the parameter values of the regression equations (V=bT − c).

Generation	b	c
G_1	0.0117~0.0145	0.0797~0.0840
G_2	0.0188~0.0221	0.1905~0.1984
G_3	0.0250~0.0341	0.4033~0.4172
G_4	0.0126~0.0156	0.0919~0.0988
G_2'	0.0192~0.0299	0.2744~0.2790

eration, together with the correlation coefficient (=r), temperature range for calculation, developmental zero (=t) and thermal constant (=K). The 95% confidence limits of the parameter values of the equations are shown in Table 2. Although average of (max. - min.) temperatures is not so different among generations ($p>0.05$) except for G_2, average of mean temperatures shifts seasonally. The regression equations also differ seasonally; the parameter values are arranged in the descending order of $G_3 > G_2 > G_4$ ($p<0.05$) $\fallingdotseq G_1$ ($p>0.05$), paralleling with seasonal change of field temperature. Developmental zero also shifts seasonally, ranging between 6.3 °C and 13.9 °C.

2. *Comparison of developmental velocity between constant and fluctuated temperature conditions*

Daily difference of field temperatures are larger in a clear weather day than in a cloudy one; (max. - min.) of temperatures averaged 10.5 °C (9.63~11.31 in 95% confidence limits) on the days of sunshine duration of 8~12 hrs, 7.5 °C (6.80~8.16) on the days of 4~8 hr sunshine duration, and 5.2 °C (4.68~5.76) on the days of 0~4 hr sunshine duration (Table 3). Even in the field conditions,

Table 3 Average of (max. - min.) temperature ± S.D. in each mean temperature class (MT class) for each sunshine duration class (SD class).

MT class \ SD class	0 ~ 4	4 ~ 8	8 ~ 12
10 ~ 15	5.90±1.79(N=6)	7.60±3.57(N=12)	10.96±4.03(N=13)
15 ~ 20	5.11±1.08(N=12)	7.45±1.99(N=21)	10.43±3.25(N=29)
20 ~ 25	5.01±1.76(N=12)	7.43±2.00(N=18)	10.15±2.42(N=17)
Total	5.23(4.67~5.79)*	7.48(6.80~8.16)*	10.47(9.63~11.31)*

* 95% confidence limit in parentheses.

Table 4 Mean temperature, (max. - min.) temperature, and sunshine duration on 24th～29th August, and on 2nd～8th September in 1975.

	Mean T (°C)	Max.−Min.(°C)	Sunshine duration (hr)
August 24	20.5	7.4	10.8
25	19.2	13.5	12.2
26	20.9	10.6	7.9
27	21.4	5.2	6.3
28	19.5	11.1	8.8
29	21.0	12.9	10.7
Average	20.4	10.12±3.38*	9.5
September 2	25.3	6.4	1.6
3	23.9	7.6	8.7
4	22.7	4.6	0.2
5	23.4	5.8	5.9
6	23.8	4.7	3.6
7	22.0	1.7	0.3
8	22.6	4.6	0.7
Average	23.4	5.06±1.72*	3.0

* 95% confidence limit.

eggs develop under relatively fluctuated temperatures during successively clear weather period, or under relatively constant temperatures during successively cloudy weather period. Two observation periods in G_3 were adopted as shown in Table 4; August 24th～29th and September 2nd～8th, to compare developmental velocity under fluctuated temperature conditions with that under constant temperature ones. In the former period (mean temperature $=20.4$ °C, average of max. - min. $=$ 10.12 °C), the velocity was less than expected at the same temperature level: 0.1804 (0.1747～0.1861 in 95% confidence limits) <0.1939($=$ expected by calculation of regression equation of G_3 in Table 1, $T=20.4$ °C). In the latter period (mean temperature $=23.4$ °C, average of max. - min. $=5.06$ °C), the velocity was larger than expected: 0.3107 (0.2840～0.3347) >0.2795. This suggests that developmental velocity is accelerated under constant temperature conditions rather than under fluctuated conditions in the field.

3. *Local difference of developmental zero*

The regression equation on eggs of Kyôto population reared under constant temperatures of 15, 20, 25 °C, $V=0.0190T-0.1389$ ($t=7.3$ °C, $K=52.6$ day-degrees), is obtained by OHSAKI (1982). To compare with this result, the regression equation was calculated by the data ($N=423$) of mean temperature and developmental velocity observed during 12 successive days from July 3rd to 14th, in which the maximum and minimum air temperature indicated the same range as OHSAKI's, ca. 15～25 °C (Table 5). The regression equation in this period was $V=0.0246T-0.2767$ ($t=11.3$ °C, $K=40.7$ day-degrees, Fig. 2 - G_2'). The 95% confidence limits of the parameters are shown as G_2' in Table 2. Developmental zero was higher in Sapporo populations than in Kyôto ones, while developmental velocity was accelerated in Kyôto rather than in Sapporo except for higher temperature conditions

Table 5 Maximum, minimum and mean air temperature on 3rd to 14th July, 1975.

	Maximum	Minimum	Mean
July 3	24.3	12.7 *	18.5
4	19.2	15.6	17.4
5	21.8	15.1	18.5
6	23.2	16.3	19.8
7	22.1	16.5	19.3
8	20.4	16.2	18.3
9	18.4	14.9	16.7
10	19.3	15.3	17.3
11	18.4	15.0	16.7
12	18.3	15.4	16.9
13	21.3	14.8	18.1
14	23.0	16.5	19.8

* outside the range of ca. 15～25℃.

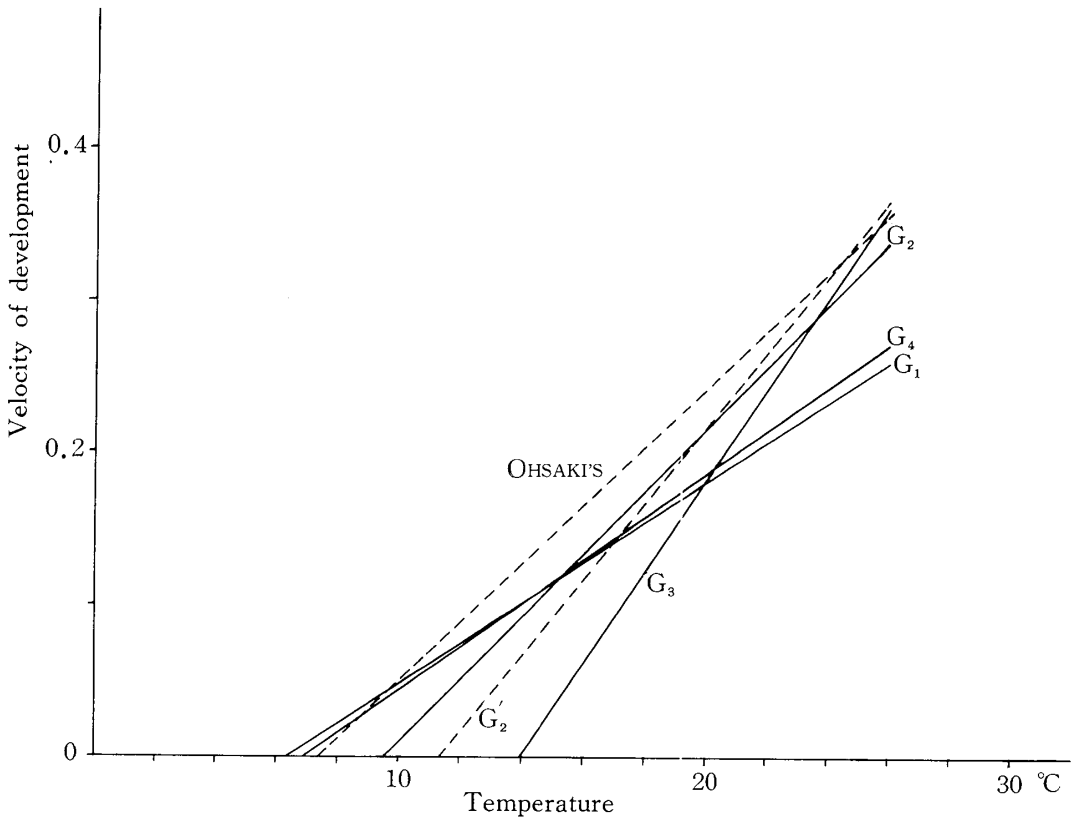

Figure 2 Regression lines of developmental velocity to mean air temperature in four generations and corrected G_2 (= G_2'), together with regression line on Kyôto population surveyed by OHSAKI (1982).

over ca. 24 °C (Fig. 2). But this local difference is a still disputable conclusion because of a discrepancy of rearing conditions between two populations, constant temperature conditions and fluctuating ones.

References

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摘　要

モンシロチョウ (*Pieris rapae crucivora* BOISDUVAL) 卵期の発育速度と野外温度との関係が調べられ，恒温条件下で発育促進がみられるとともに，発育限界温度および有効温量が発生世代で，そして，おそらく地理的にも異なることが示唆された。